# A digital cast-free clinical workflow for oral rehabilitation with removable partial dentures: A dental technique

Al-Haj Husain, Nadin ; Özcan, Mutlu ; Schimmel, Martin ; Abou-Ayash, Samir

Abstract: The present report describes a technique for a digital cast-free clinical workflow for the fabrication of a combined tooth-implant-supported removable partial denture. This technique comprises digital intraoral scanning, computer-aided design, and subtractive computer-aided manufacturing for the denture base, denture teeth, and crowns and additive computer-aided manufacturing for the denture framework (CAD-CAM).

DOI: https://doi.org/10.1016/j.prosdent.2019.05.008



Originally published at:
Al-Haj Husain, Nadin; Özcan, Mutlu; Schimmel, Martin; Abou-Ayash, Samir (2020). A digital cast-free clinical workflow for oral rehabilitation with removable partial dentures: A dental technique. Journal of Prosthetic Dentistry, 123(5):680-685.
DOI: https://doi.org/10.1016/j.prosdent.2019.05.008

Description of a novel digital cast-free clinical workflow for oral rehabilitation with removable partial dentures: A technical report

Nadin Al-Haj Husain, DDS,[a*] Mutlu Özcan DDS, DMD, PhD,[b] Martin Schimmel, DDS,[c] Samir Abou-Ayash, DDS[d]

[a]Specialization Candidate, Department of Reconstructive Dentistry and Gerodontology, School of Dental Medicine, University of Bern, Switzerland.

[b]Professor and Head, Dental Materials Unit, Center for Dental and Oral Medicine, University of Zurich, Zurich, Switzerland.

[c]Professor, Department of Reconstructive Dentistry and Gerodontology, School of Dental Medicine, University of Bern, Switzerland.

[d]Head of Section for Digital Implant- and Reconstructive Dentistry [DIRecD], Department of Reconstructive Dentistry and Gerodontology, School of Dental Medicine, University of Bern, Switzerland.

Corresponding author:

Nadin Al-Haj Husain

Specialization Candidate

Department of Reconstructive Dentistry and Gerodontology

School of Dental Medicine

University of Bern

SWITZERLAND

Email: nalhaj88@gmail.com

JPD-2018-196

DENTAL TECHNIQUE

# A digital cast-free clinical workflow for oral rehabilitation with removable partial dentures: A dental technique

## ABSTRACT

The present report describes a technique for a digital, cast-free, clinical workflow, for the fabrication of a combined tooth-implant-supported removable partial denture. This technique comprises digital intraoral scanning, computer-aided design and computer-aided manufacturing (CAD-CAM), in a subtractive way for the denture base, denture teeth, and crowns as well as, in an additive way, for the denture framework.

## INTRODUCTION

Removable complete dentures (CDs) are a common treatment option for edentulous adults who cannot receive implant-supported prostheses because of anatomical, financial, or psychological reasons.[1] However, complete edentulism is a decreasing public oral health concern, while the population of partially dentate adults is increasing.[2,3] A shift from edentulism toward partial edentulism is taking place and is estimated higher than 20% in some regions.[4] Nevertheless, there are regions where tooth extraction and the delivery of complete dentures are still the only affordable options.[4]

As clinicians and patients seek the reconstruction of teeth and oral structures to improve appearance, enhance masticatory efficiency, and improve phonetics,[5] clasp retained removable partial dentures (RPDs) provide a treatment option to replace missing oral hard and soft structures. However, the fabrication of RPD frameworks is a time-consuming and therefore cost-intensive procedure, as the standard method is still the lost wax-technique.[6]

Additive manufacturing by means of selective laser melting (SLM) results in more efficient framework fabrication[7] and provides frameworks with superior mechanical properties compared with those fabricated with conventional casting techniques.[8-10] Nevertheless, reports of a digital workflow for the fabrication of clasp retained RPDs are sparse,[11-14] and the authors are unaware of a complete clinical workflow, including all fabrication steps. Therefore, the present technical report describes a novel technique of a digital, cast-free, clinical workflow for the fabrication of a combined tooth-implant-supported RPD employing digital scanning, processing, and manufacturing procedures.

## DENTAL TECHNIQUE

Conventional denture fabrication techniques involve a complex sequence of multiple clinical and laboratory steps,[14,15] the first step being preliminary impressions and production of custom trays. For RPDs, tooth preparation might be needed. Subsequently, definitive impressions are made using custom trays, followed by fabrication of occlusion rims, horizontal and vertical occlusal relation records, the arrangement of the denture teeth, clinical evaluation, resin processing, and denture delivery.

The dental digital clinical workflow consists of 3 steps: acquisition or digitalization, data processing (CAD), and manufacturing (CAM).[15,16]

1. Make digital scans using an intraoral scanning device (TRIOS 3 Basic; 3Shape) according to the manufacturer’s protocol. Scan the maxillary (antagonistic scan) and mandibular (pre-

preparation scan) arches (Fig. 1), as well as an initial digital record of the interocclusal relation (occlusal scan) (Fig. 2).

2. Perform digital cast analysis: The analysis of the digital casts should be performed using a CAD software (3Shape CAD Points, 3Shape). Based on these analyses, an initial virtual framework design should be made (Fig. 3)[17], which enables the clinician to perform the tooth preparation based on the planned framework design. The digital scan data should be used to produce occlusal bite rims to determine the definitive vertical and horizontal jaw relation.
3. Make a final intraoral scan of the prepared teeth only, and record maxilla-mandibular relation. The third and last intraoral scan should then be performed at the same clinical appointment using the occlusal bite rims (Fig. 4).
4. Design the denture framework digitally: Eliminate undercut regions and shoulders of the clasps trimmed at engaging points, using the 3Shape CAD points software. Design framework components, namely connectors (major and minor), rests and clasps digitally using a haptic device (Touch X; 3D Systems) (Fig. 5). Combine framework-components digitally and design the entire framework. Calculate controlled support structures in order to avoid deformation during cast fabrication. Convert three-dimensional information of framework as a stereolithography (STL) file into a rapid prototyping (RP) system (M270; EOS) for RPD framework fabrication.
5. Fabricate the denture framework additively by rapid prototyping (RP): Use a laser beam in an SLM technique to weld the cobalt-chromium alloy powder (Starbond Easy; S&S Scheftner Dental Alloys) layer by layer to create the metal framework (Fig. 6).[18] Remove

supporting structures, polish the framework and evaluate intraoral fitness clinically (Fig. 7).[19]

6. Fabricate the denture base in a subtractive CAD/CAM workflow and assemble all components (framework, denture teeth, denture base) cast-free: Design and mill the denture base and teeth out of PMMA blocks (SR Vivodent CAD and IvoBase CAD; Ivoclar) in subtractive manufacturing manner using a conventional milling machine (PrograMill One; Ivoclar). Merge the denture parts with auto-polymerized resin (ProBase Cold; Ivoclar) (Fig. 8), in a model-free way (Fig. 9) using the repositioning aids and the parallel walled framework design.
7. Deliver the final denture to the patient: Try the final denture in the patient´s mouth in and verify the marginal fit, proximal contact points, color integration with the adjacent teeth and hygiene maintenance capability (Fig. 10). Check the internal fit (Fig. 11) and polymerize dalbo-Plus attachments (Cendres+Métaux SA Medtech) directly into the final denture, using an auto-polymerizing (Paladur; Kulzer GmbH) resin.

Minor sore spots were treated in the first follow-up visit, and the patient was included in a semi-annual revision protocol. The overall treatments costs, including the dental laboratory work, were calculated and compared to the costs of a conventionally fabricated RPD, resulting in an overall cost reduction of approximately 25% (3026 vs. 4015 Swiss Francs).

**DISCUSSION**

The used CAD-CAM technology has the benefits of simplifying treatment procedures by reducing time and appointments. The digital tools for analyzing undercut areas and defining an insertion and removal path for the final denture is more accurate, compared to conventional analyses.[12] However, careful clinical data acquisition with precise execution of clinical procedures is essential.[20] Especially for removable dentures, it is difficult to scan the distally extended and broad edentulous areas, due to the functionality of an intraoral scanner that stitches narrow areas. Furthermore, the technique is image-based, which makes the recording of a functional impression impossible.[11] Further development of IOS devices would surely be beneficial for the described digital workflow.[21]

The fit of digital RPDs, fabricated with RP techniques exhibit similar marginal and internal gap values compared to those fabricated with conventional impression techniques.[10,22,23] Selective laser melting technology allows manufacturing of metallic3D objects in cross-sections. The superior material properties of frameworks manufactured by selective laser melting techniques might lead to a subtle design of the clasps, which could finally result in a reduced caries incidence and a more aesthetic treatment outcome. Furthermore, the number of prosthetic complications e.g. fractures of clasps or frameworks could be reduced. The high precision of laser melting reduces the imprecision due to manual processing and thereby increase denture quality while reducing overall treatment, follow-up costs, and material waste. The digitally fabricated frameworks contain a reinforced scaffold allowing possible later merging compared to the conventional saddle designed RPDs. Digitally developed dentures allow multiple clinical try-ins including vertical bite height increases through a possible provisional merging of the denture teeth and bases while refabricating and modification possibility is still secured.[24]

Initial acquisition costs of the digital devices and technologies might be considered as a limitation for the application of this technique. However, it is possible to outsource the manufacturing process to big CAD-CAM centers, which would also lead to a further decrease in manufacturing costs. A hybrid pathway using both, digital and conventional techniques could also be considered, as an alternative to the outsourcing of the framework fabrication.

**SUMMARY**

Today, the developments in technological processing methods allow the prosthetic rehabilitation throughout designing, processing and fabricating of cast-free removable and fixed partial dentures. The technique shows great potential as it fulfills precision and aesthetical demands while reducing costs and time. For future research, prospective studies investigating this technique should be conducted, to allow a recommendation regarding the introduction of digital RPDs in the daily dental practice and achieve higher precision of scanning methods especially in edentulous areas.

**REFERENCES**

1. Baelum V, VanPalenstein Helderman W, Hugoson A, Yee R. A global perspective on changes in the burden of cares and periodontitis: implications for dentistry. J Oral Rehabil 2007;34:872-906.

2. Schneider C, Zemp E, Zitzmann NU. Oral health improvements in Switzerland over 20 years. Eur J Oral Sci 2017;125:55-62.

3. Cooper LF.The current and future treatment of edentulism. J Proshtodont 2009;18:116-227.

4.Hugoson A, Koch G, Göthberg C, Helkim AN, Lundin SA, Nordery O, Sjödin B, Sondell K. Oral health of individuals aged 3-80 years in Jönköping, Sweden during 30 years (1973-2003). II. Review of clinical and radiographic findings. Swed Dent J 2005;29:139-55.

5. Benso B, Kovalik AC, Jorge JH, Campanha NH. Failures in the rehabilitation treatment with removable partialdenture. Acta Odontol Scand 2013;71:1351-5.

6. Eggbeer D, Bibb R, Williams R. The computer-aided design and rapid prototyping fabrication of removable partial denture frameworks. Mech Eng H. 2005;219:195-201.

7. Aliufui-Segbaya F, Williams RJ, George R. Additive manufacturing : A novel method for fabricating cobalt-chromium removable partial denture frameworks. Eur J Prosthodont Restor Dent 2017;25:73-8.

8. Takaichi A, Suyalatu , Nakamoto T, Joko N, Nomura N, Tsutsumi Y, Migita S, Doi H, Kurosu S, Chiba A, Wakabayashi N, Igarashi Y, Hanawa T. Microstructures and mechanical properties of Co-29Cr-6Mo alloy fabricated by selective laser melting process for dental applications. J Mech Behav Biomed Mater 2013;21:67-76.

9. Kim Hr, Jang SH, Kim YK, Son JS, Min BK, Kim KH, Kwon TY. Microstructures and mechanical properties of Co-Cr dental alloys fabricated by three CAD/CAM-based processing

techniques. Materials 2016;20:9.

10. Zhou Y, Li N, Yan J, Zeng Q. Comparative analysis of the microstructures and mechanical properties of Co-Cr dental alloys fabricated by different methods. J Prosthet Dent 2018;120:617-23.

11. Ye H, Ning J, Li M, Niu L, Yang J, Sun Y, Zhou Y. Preliminary clinical application of removable partial denture frameworks fabricated using computer-aided design and rapid prototyping techniques. Int J Prosthodont 2017;348-53.

12. Mansour M, Sanchez E, Machado C. The use of digital impressions to fabricate tooth-supported partial removable dental prosthese: A clinical Report. J Prosthodont 2016;25:495-7.

13. Virard F, Venet L, Richert R, Pfeffer D, Viguié G, Bienfait A, Farges JC, Ducret M. Manufacturing of an immediate removable partial denture with an intraoral scanner and CAD-CAM technology: a case report. BMC Oral Health 2018;18:120.

14. Williams RJ, Bibb R, Rafik T. A technique for fabricating patterns for removable partial denture frameworks using digitized casts and electronic surveying. J Prosthet Dent 2004;91:85-8.

15. Bohnenkamp DM. Removable partial dentures: clinical concepts. Dent Clin North Am 2014;58:69-89.

16. Burzynski JA, Firestone AR, Beck FM, Fields HW Jr, Deguchi T. Comparison of digital scanners and alginate impressions: Time and patient satisfaction. Am J Orthod Dentofacial Orthop 2018;153:534-41.

17. Mangano F, Gandolfi A, Luongo G, Logozzo S. Intraoral scanners in dentistry: a review of the current literature. BMC Oral Health 2017;17:149.

18. Murray MD, Darvell BW. The evolution of the complete denture base. Theories of complete denture retention: a review. Part 1. Aust Dent J 1993;38:216-9.

19. Mansour M, Sanchez E, Machado E. The use of digital impression to fabricate tooth-supported partial removable dental prostheses: a clinical report. J Prosthodont 2016;25;495-7.

20. Budak I, Vukelić D, Bračun D, Hodolič J, Soković M. Pre-processing of point-data from contact and optical 3S digitization sensors. Sensors 2012;12:1100-26.

21. Hayama H, Fueki K, Wadachi J, Wakabayashi N. Trueness and precision of digital impressions obtained using an intraoral scanner with different head size in the partially edentulous mandible. J Prosthet Res 2018;62:347-52.

22. Tregerman I, Renne W, Kelly A, Wilson D. Evaluation of removable partial denture frameworks fabricated using 3 different techniques. J Prosthet Dent 2019 [Epub ahead of print].

23. Almufleh B, Emami E, Alageel O, de Melo F, Seng F, Caron E, Nader SA, et al. Patient satisfaction with laser-sintered removable parial dentures: A crossover pilot clinical trial. J Prosthet Dent 2018;119:560-7.

24. Yan X, Lin H, Wu Y, Bai W. Effect of two heat treatments on mechanical properties of selective-laser-melted Co-Cr metal-ceramic alloys for application in thin removable dentures. J Prosthet Dent 2018;119:1028.

**FIGURES**

Figure 1. Initial intraoral situation.

Figure 2. A, Initial digital scan of lower jaw. B, record of interocclusal relationship.

Figure 3. A, Digital surveying of initial digital scan. B, measuring of undercut areas.

Figure 4 A, Frontal. B, lateral view of digital interocclusal relationship record, using a occlusion rim.

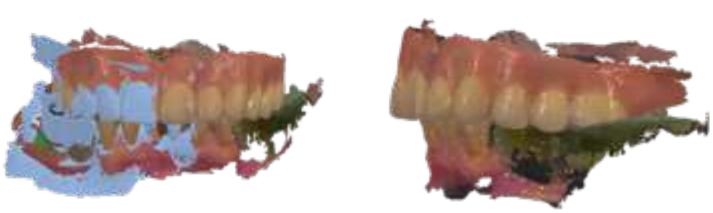

Figure 5. Occlusal view of digitally designed framework

Figure 6. Lateral view of additively manufactured cobalt-chromium alloy framework.

Figure 7. A+B, Intraoral framework try-in.

Figure 8. A, Occlusal upper. B, lower view of framework, denture base and denture teeth.

Figure 9. A, Lower. B, upper view of final RPD.

Figure 10. A, Lateral right. B, frontal. C, lateral left view of RPD in situ.

Fig. 11. Determining denture fit by using a polyether impression.